CS 349: Networks Lab

(January-May 2020)

Assignment – 4: Network Simulation Using ns-3

Submission Deadline: 11:55 pm on Wednesday, 15th April 2020 (hard deadline)

In this assignment you need to simulate a computer network for a given application using the discrete event network simulator **ns-3**. You can download the software and documentation of **ns-3** from the website https://www.nsnam.org.

The assignment will be solved in groups where each group, comprised of **3 members**, needs to work on an application assigned to it. The group membership information is given in this document. The applications' network specifications, the required experiments, and related questions are also given in this document.

Follow the general instructions given below and any specific instructions mentioned in the application description.

General Instructions:

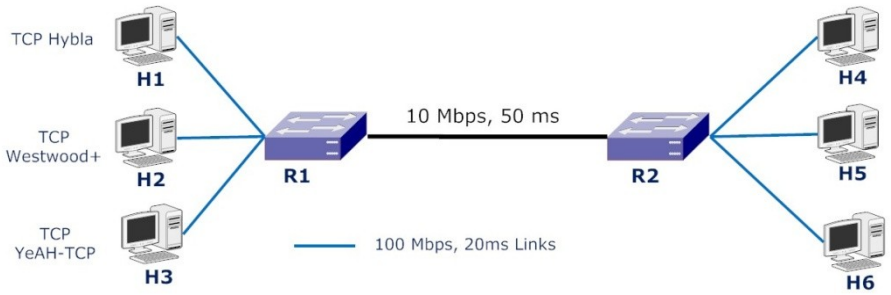
1. Each group needs to simulate one application assigned to it and make one single submission on Moodle. Only one member from a group needs to make the submission. The information about the allocation of applications to groups is contained in **Table 1** given below. Group members' information is given in **Table 2**.
2. Install **ns-3** on your computer, write programs and simulate the network described in the given application assigned to you, perform the required experiments, and answer the given questions.
3. Use **ns-3**'s **Flow Monitor** module to collect and store the performance data of network protocols from the simulation. **Do not use PCAP + Wireshark for the trace collection**. No marks will be awarded if your application uses PCAP file for trace collection.
4. Submit your set of source code files, and your report containing the graphs and the answers, for the assigned application as a zipped file on Moodle (maximum file size is 1 MB) by the deadline of **11:55 pm on Wednesday, 15th April 2020 (hard deadline)**. The **ZIP file's name should be the same as your group number**, for example, "Group_4.zip", or "Group_4.rar", or "Group_4.tar.gz".
5. The assignment will be evaluated through viva voce in your lab during your lab session on **Wednesday, 22nd April 2020 (9:00 am to 11:55 am)** where you also need to explain your source codes and execute them in front of the evaluator (evaluation schedule and TA allocation will be notified in due time).
6. **Write your own source codes and do not copy from any source. Plagiarism and use of unfair means will be penalised by awarding NEGATIVE marks (equal to the maximum marks for the assignment).**

Table 1: Allocation of applications to groups

Application Number	Group Numbers
1	1, 7, 13, 19, 25, 31, 37, 43
2	2, 8, 14, 20, 26, 32, 38, 44
3	3, 9, 15, 21, 27, 33, 39, 45
4	4, 10, 16, 22, 28, 34, 40, 46
5	5, 11, 17, 23, 29, 35, 41, 47
6	6, 12 ,18 ,24 ,30 ,36 ,42 ,48

Application #1:

Analyse and compare TCP Hybla, TCP Westwood+, and TCP YeAH-TCP performance. Select a Dumbbell topology with two routers R1 and R2 connected by a (10 Mbps, 50 ms) wired link. Each of the routers is connected to 3 hosts, i.e. H1, H2, H3 (i.e. senders) are connected to R1, and H4, H5, H6 (i.e. receivers) are connected to R2. The hosts are attached with (100 Mbps, 20 ms) links. Both the routers use drop-tail queues with queue size set according to bandwidth-delay product. Senders (i.e. H1, H2 and H3) are attached with TCP Hybla, TCP Westwood+, and TCP YeAH-TCP agents, respectively. Choose a packet size of 1.5 KB and perform the following tasks. Make appropriate assumptions wherever necessary.



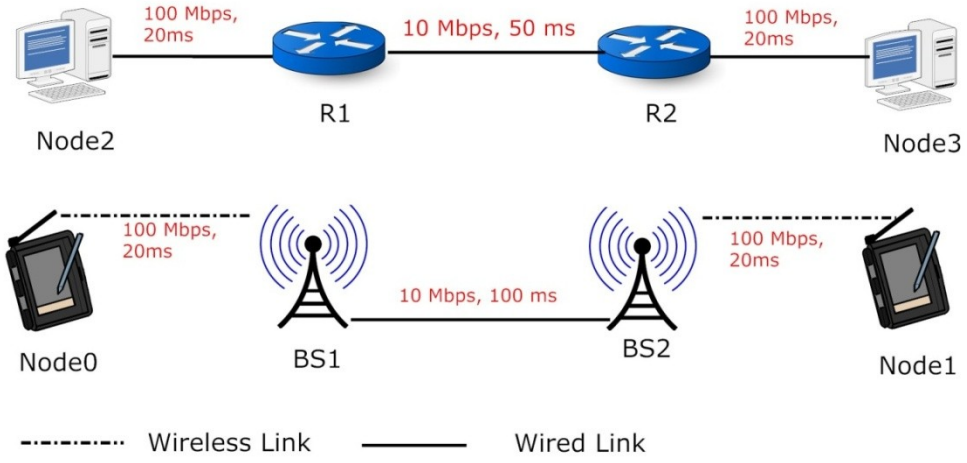
1. Start only one flow and analyse the throughput over sufficiently long duration. Mention how you select the duration. Plot the evolution of congestion window w.r.t. time. Perform this experiment with all the flows attached to all the three sending agents.

2. In the next experiment, start 2 other flows sharing the bottleneck link while the first one is in progress and measure the throughput (in Kbps) of each flow. Plot the throughput and evolution of the TCP congestion window for each of the flow at a steady-state. Report the maximum throughput observed for each of the flows.

3. Measure the congestion loss and the goodput over the duration of the experiment for each of the flows.

Application #2:

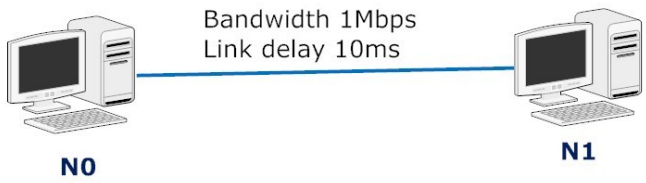
Compare the performance of TCP over wired and wireless networks. Consider a topology as described below. The network consists of two TCP sources Node0 and Node2, corresponding to two TCP destinations Node1 and Node3 respectively. Node2 and Node3 come in wired domain with two routers R1 and R2 (connected by a {10 Mbps, 50 ms} wired link) between them. Both the routers use drop-tail queues with queue size set according to bandwidth-delay product. Node0 comes in domain of Base Station 1 (BS1) and Node1 comes in domain of Base Station 2 (BS2). BS1 and BS2 are connected by a (10 Mbps, 100 ms) wired link. The hosts, i.e. Node0, Node1, Node2, Node3 are attached with (100 Mbps, 20ms) links to routers or base stations (as shown in the figure below). The sources (Node0 and Node2)) use three TCP agents (i.e. TCP Westwood, TCP Veno and TCP Vegas) to generate three different TCP flows. Study and plot the fairness index (Jain's fairness index) and throughput change when the TCP packet size is varied; all the other parameter values are kept constant. You should use the following TCP packet size values (in Bytes): 40, 44, 48, 52, 60, 250, 300, 552, 576, 628, 1420 and 1500 for your experiments. The throughput (in Kbps) and fairness index must be calculated at steady-state. Make appropriate assumptions wherever necessary.



Application #3:

Create a topology of two nodes N0 and N1 connected by a link of bandwidth 1 Mbps and link delay 10 ms. Use a drop-tail queue at the link. Set the queue size according to bandwidth-delay product. Create a TCP agent (type of the agent specified below) and FTP traffic at N0 destined for N1. Create 5 CBR traffic agents of rate 250 Kbps each at N0 destined for N1. Make appropriate assumptions wherever necessary. The timing of the flows are as follows:

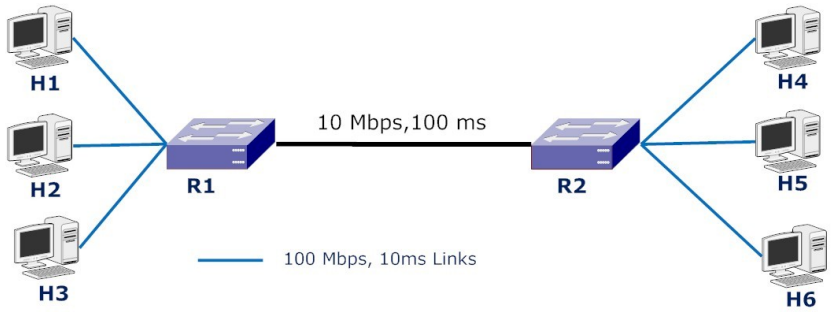
- FTP starts at 0 sec and continues till the end of simulation.
- CBR1 starts at 200 ms and continues till end.
- CBR2 starts at 400 ms and continues till end.
- CBR3 starts at 600 ms and stops at 1200 ms.
- CBR4 starts at 800 ms and stops at 1400 ms.
- CBR5 starts at 1000 ms and stops at 1600 ms.
- Simulation runs for 1800 ms.



1. Plot graph(s) of TCP congestion window w.r.t. time for following 5 TCP congestion control algorithm implementations, and describe the TCP congestion control algorithms' behaviour.
    - Case 1: use TCP New Reno
    - Case 2: use TCP Hybla
    - Case 3: use TCP Westwood
    - Case 4: use TCP Scalable
    - Case 5: use TCP Vegas
2. Draw a graph showing cumulative TCP packets dropped w.r.t. time comparing above 5 TCP congestion control algorithm implementations.
3. Draw a graph showing cumulative bytes transferred w.r.t. time comparing above 5 TCP congestion control algorithm implementations.

Application #4:

Compare the effect of buffer size on TCP and UDP flows. Select a Dumbbell topology with two routers R1 and R2 connected by a (10 Mbps, 100 ms) link. Each of the routers is connected to 3 hosts, i.e. H1, H2, H3 are connected to R1, and H4, H5, H6 are connected to R2. All the hosts are attached to the routers with (100 Mbps, 10 ms) links. Both the routers (i.e. R1 and R2) use drop-tail queues with equal queue size set according to bandwidth-delay product. Choose a packet size of 1.5 KB. Start 3 TCP New Reno flows, and after a while start 3 CBR over UDP flows each with 20 Mbps. These flows are randomly distributed across H1, H2 and H3. Increase the rate of one UDP flow up to 100 Mbps and observe its impact on the throughput of the TCP flows and the other UDP flow. Vary the buffer size in the range of 10 packets to 800 packets and repeat the above experiments to find out the impact of buffer size on the fair share of bandwidth and plot the necessary graphs. Make appropriate assumptions wherever necessary.

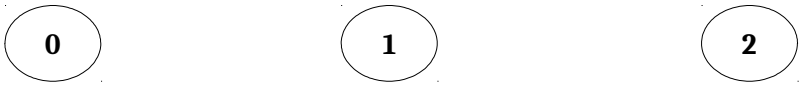


Application #5:

Using the network simulator ns-3, study the characteristics of IEEE 802.11. For the purpose of experiment, use the topology as follows. There are 3 nodes in the network located in a straight line at locations 200*i, with i=0, 1, 2. Node 0 and Node 2 both have TCP traffic to Node 1 (started randomly within 1 to 5 seconds of starting the simulation). Consider TCP Westwood+ or TCP Hybla for the TCP agents at Node 0 and Node 2, respectively. You have to run the simulations and measure the following from the trace output (the averages are taken over all the nodes). Do not use PCAP file for collecting the trace. Use Flow Monitor module in ns-3 for trace collection. *No marks will be given if you consider PCAP trace with Wireshark*.

1. Average bandwidth spent in transmitting RTS, CTS, and ACK.
2. Average bandwidth spent in transmitting TCP segments and TCP acks.
3. Average bandwidth wasted due to collisions.
4. TCP throughput (number of acknowledged bytes per unit time) at each node.

You have to run the simulations for 50 seconds each with different RTS thresholds (i.e. 0, 256, 512 and 1024 bytes) and TCP segment size of 1000 bytes. You can use scripts for trace file analysis and to plot the results. Make appropriate assumptions wherever necessary.

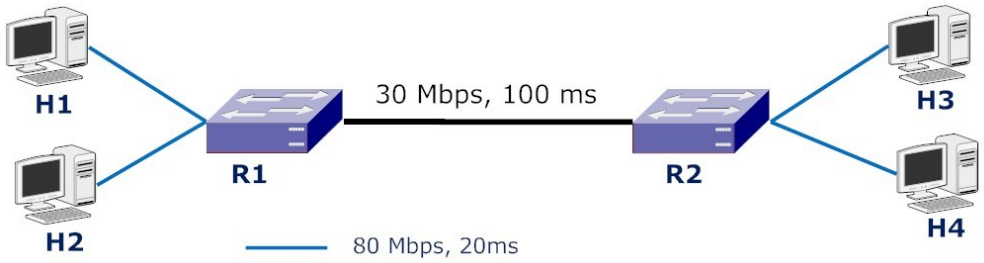


Application #6:

The objective is to compare the effect of CBR traffic over UDP agent and FTP traffic over TCP agent. Consider a TCP agent from TCP HighSpeed, TCP Vegas and TCP Scalable for the FTP traffic. Consider a Dumbbell topology with two routers R1 and R2 connected by a wired link (30 Mbps, 100 ms), and use drop-tail queues with queue size set according to bandwidth-delay product of the link. Each of the routers is connected to 2 hosts, i.e. H1, H2 are connected to R1, and H3, H4 are connected to R2. The hosts are attached to the routers with (80 Mbps, 20ms) links. The CBR traffic over UDP agent and FTP traffic over TCP agent are attached to H1 and H2 respectively. Choose appropriate packet size for your experiments and perform the following:

1. Compare the delay (in sec) and throughput (in Kbps) of CBR and FTP traffic streams when only one of them is present in the network. Plot the graphs for the delay (in sec) and throughput (in Kbps) observed with different packet sizes.

2. Start both the flows at the same time and also at different times. Also, compare the delay (in sec) and throughput (in Kbps) of CBR and FTP traffic streams. Plot the graphs for the delay (in sec) and throughput (in Kbps) observed with different packet sizes.



Make appropriate assumptions wherever necessary.

Table 2: Group Members corresponding to each Group

Group ID	Roll	Name	Application ID Assigned
1	150123034	ROHIT KUMAR	1
1	170123014	BARISH BHAGAT	1
1	170123026	KONDRU SURAJ	1
1	170123006	ANKIT TRIPATHI	1
2	170101055	ROHAN NIGAM	2
2	170123036	MOHIT DHAKA	2
2	170123037	MOHIT KUMAR MEENA	2
3	170101005	AMAN MISHRA	3
3	170101031	KEERTI HARPAVAT	3
3	170101049	Priyanshu Singh	3
4	170101081	UDBHAV CHUGH	4
4	170123013	BAGAL SATEJ BABANRAO	4
4	170123052	TANYA CHAUHAN	4
5	170123015	BOJJA SAI PREETHAM	5
5	170123024	KESHETTI SAI KUMAR	5
5	170123031	MALISETTI KIRAN KARTHEEK	5
6	170101036	MANI MANNAMPALLI	6
6	170101068	SUNNY KUMAR	6
6	170101087	SIDDHARTH AGARWAL	6
7	170101084	MAYANK BARANWAL	1
7	170123017	DEV PRIYA GOEL	1
7	170123059	SHRUTI DINESH AGARWAL	1
8	170101035	MANAN GUPTA	2
8	170123011	ASHISH AGARWAL	2
8	170123038	MRIGANKA BASU ROY CHOWDHURY	2
9	170101043	PARTHA PRATIM MALAKAR	3
9	170101048	PRANSHU SRIVAS	3
9	170101070	THAHIR MAHMOOD POOVADA	3
10	170101039	NAGULAPALLI KASI VENKATA SAI KIRAN	4
10	170101051	RAJANALA HARSHAVARDHAN REDDY	4
10	170123016	CHINDAM SUJANA MAITHILI	4
11	170101029	KAPIL JANGID	5
11	170101044	PARVINDAR SINGH	5
11	170101057	RUTVIK GHUGHAL	5
12	170101077	VEMURI SAHITHYA	6
12	170123039	NAKKA LAHARI	6
12	170123054	TUMARADA ADITYA	6
13	170101054	RISHI PATHAK	1
13	170101063	SHIVAM BANSAL	1
13	170101088	SHASHANK SHARMA	1
14	170101040	NAKKA SRIHARSHA	2
14	170123025	KOMMINENI NIKHIL	2
14	170123028	KRISHNA PRIYATAM D	2
15	170101001	AAYUSH PATNI	3
15	170101052	RASHI SINGH	3
15	170101066	SOUMIK PAUL	3
16	170101033	LUCKY	4
16	170101034	MAKHARIA AAYUSH	4
16	170123021	HEMANT YADAV	4

Group ID	Roll	Name	Application ID Assigned
17	170123004	ADITYA RAJ	5
17	170123040	PARV SOOD	5
17	170123043	SAHILPREET SINGH THIND	5
18	160101011	AKHIL CHANDRA PANCHUMARTHI	6
18	170101017	CH ROHITH RAVI PRABHU TEJA	6
18	170101050	PULIKONDA ROOP SAI RAKESH GUPTA	6
19	170101006	AMAN RAJ	1
19	170123029	KUSHAGRA MAHAJAN	1
19	170123034	MIHIR YADAV	1
20	170101074	UMANG	2
20	170123051	TANVI OHRI	2
20	170123053	TEJASVEE PANWAR	2
21	170101078	VINEET MALIK	3
21	170101080	VIVEK KUMAR	3
21	170101085	Sparsh Sinha	3
22	170101019	CHIRAG GUPTA	4
22	170101076	VAKUL GUPTA	4
22	170101082	LAVISH GULATI	4
23	170101026	HARDIK KATYAL	5
23	170101030	KARTIK GUPTA	5
23	170101075	UTKARSH JAIN	5
24	170123023	KEDAR NATH	6
24	170123056	PRATHIK.S.NAYAK	6
24	170123064	AGNIV BANDYOPADHYAY	6
25	170101060	SANCHIT	1
25	170123018	GARVIT MEHTA	1
25	170123020	harit gupta	1
26	170101002	ABHISHEK JAISWAL	2
26	170101038	MAYANK WADHWANI	2
26	170123007	ANKUR PRAMOD INGALE	2
27	170101067	SOURABH JANGID	3
27	170101071	THEEGALA RAKESH REDDY	3
27	170101073	TUSHAR RAJENDRA BHUTADA	3
28	170101009	ANUBHAV TYAGI	4
28	170101045	Piyush Gupta	4
28	170101053	RAVI SHANKAR	4
29	160101017	AUTONU KRO	5
29	170101023	FUGARE ASHISH DILEEP	5
29	170101027	KADAM KIRAN ZATINGRAO	5
30	170101011	ARANYA ARYAMAN	6
30	170101015	AVNEET SINGH CHANNA	6
30	170101041	NAVEEN KUMAR GUPTA	6
31	170101059	Sachin Giri	1
31	170101061	SAYAK DUTTA	1
31	170123010	ARYAN RAJ	1
32	170101013	ARYAN AGRAWAL	2
32	170101014	AVIRAL GUPTA	2
32	170101022	DEVANSH GUPTA	2

Group ID	Roll	Name	Application ID Assigned
33	170101064	SHUBHAM KUMAR	3
33	170101065	SHYAM SUNDAR RAV	3
33	170101079	VINIT KUMAR	3
34	170101037	MAYANK CHANDRA	4
34	170101046	PRABHAT KUMAR	4
34	170123050	SUMEDH RAVI JOURAS	4
35	170123001	AAYUSH BANSAL	5
35	170123057	KARTIK SETHI	5
35	170123058	ARUN KUMAR	5
36	170101008	ANNANYA PRATAP SINGH CHAUHAN	6
36	170101012	ARPIT GUPTA	6
36	170101086	SHIVANG DALAL	6
37	170123027	KOTTA PREM SUJAN	1
37	170123035	MOGILLAPALLI NIKHIL	1
37	170123042	S SAI VAMSHI	1
38	170101007	ANIKET RAJPUT	2
38	170101020	DEEPAK GAMI	2
38	170101047	PRANAY GARG	2
39	170101056	ROUNAK PARIHAR	3
39	170101058	RYTHUM SINGLA	3
39	170101083	UTKARSH SANTOSH MISHRA	3
40	170123060	TRIKAY NALAMADA	4
40	170123061	MAHFOOZUR RAHMAN KHAN	4
40	170123062	DIVYANSH MANGAL	4
41	170123003	ABHINAV R	5
41	170123008	ARAV GARG	5
41	170123063	JOEL RAJA SINGH	5
42	170101021	DEVAISHI TIWARI	6
42	170123048	SIDDHANT SINHA	6
42	170123022	JAYANT PATIDAR	6
43	170123012	AYUSH DALIA	1
43	170123033	MAYANK SAHARAN	1
43	170123044	SAKSHI SHARMA	1
44	170123002	ABHINAV ANAND	2
44	170123041	RUPAM SAHU	2
44	170123045	SAURABH KUMAR	2
45	170123019	GARVIT SARJARE	3
45	170123032	MANNE HEMA PRIYA	3
45	170123046	SHALINI KUMARI	3
46	170101004	AJINKYA SHIVASHANKAR SHIVASHANKAR	4
46	170101025	HANSRAJ PATEL	4
46	170101003	ADITYA VARDHAN GARA	4
47	170101016	BANDAGONDA SHRI RAAM REDDY	5
47	170101018	CHALUMURU BHAVANI DATT	5
47	170101024	GEDDAM IKYA VENUS	5
47	160101074	Sumedh Manwar	5
48	170101028	KANCHUGANTLA RHYTHM	6
48	170101032	KETHAVATH NAVEEN	6
48	170101042	NAYANJYOTI DEURY	6
49	170123005	ANKIT KUMAR KANOJIYA	6